ERDC/CHL SR-06-2

Coastal and Hydraulics Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Navigation Systems Research Program

Navigation Lock and Dam Inspection and Emergency Repairs Workshop Summary

John E., Hite, Jr., James E. Clausner, and Dinah N. McComas, editors

September 2006

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Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Abstract: The U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory hosted a "Navigation Lock and Dam Inspection and Emergency Repairs" workshop on 18-20 April 2006. The workshop was sponsored by the Navigation Systems Research Program and was attended by over 70 people from the Corps Districts, Divisions, and the ERDC laboratories as well as industry representatives. The primary purposes of the workshop were to examine current procedures used by the Corps for inspection and emergency repairs by presenting case studies and experiences and follow up on these discussions with suggestions and recommendations for improvement. Ongoing ERDC research and development in the areas of inspection and emergency repairs was also presented. The proceedings from the workshop will be available in the near future on the CHL Web site.

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Unit Conversion Factors

Multiply	By	To Obtain
feet	0.3048	meters
pounds (mass)	0.45359237	kilograms

Preface

The workshop summary reported herein were authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), at the request of the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The workshop was held at the Coastal and Hydraulics Laboratory on 18-20 April 2006. The workshop was sponsored by the Navigation Systems Research Program and coordinated by Dr. John E. Hite, Jr., James E. Clausner, and Dinah McComas of the Coastal and Hydraulics Laboratory (CHL) under the general supervision of Dr. Rose Kress, Chief, Navigation Division, CHL; Dr. William Martin, Deputy Director, CHL; and Thomas Richardson, Director, CHL.

James Crutchfield, Rusty Henderson, Donna Richey, Lorraine Smithhart, and Brenda Martin, CHL, assisted in the preparation and planning for the workshop.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

1 Introduction and Background

Navigation Systems Research Program

The Navigation Systems Research Program (NSRP) is a multi-year, multi-disciplined research and development program funded by Headquarters, U.S. Army Corps of Engineers (HQUSACE), to provide field offices with new technologies, improved tools, and better guidance to accomplish the Navigation mission. As part of this program, workshops are sponsored periodically to bring together personnel from the District Offices, the U.S. Army Engineer Research and Development Center (ERDC) laboratories, and industry to present ongoing research and development and discuss future efforts. The Navigation Lock and Dam Inspection and Emergency Repairs workshop was one of the first sponsored by the program.

The workshop announcement shown in Appendix A was sent to Division and District offices in July 2005 to solicit input for the workshop. The final program for the workshop was put together from the input received.

Problem

Due to age and reduced funds for maintenance and rehabilitation, many Corps navigation locks and dams are in danger of failure. Inspecting the locks and dams, particularly the underwater portions, is difficult. Also, when failures occur (e.g., in lock gates or dam gates), existing methods to mitigate the failure are often difficult and time-consuming to install, and effectiveness is in some cases marginal. Since several Corps District offices are faced with similar situations, a workshop was considered to be a good way to present current practices.

Purpose of workshop

The primary purposes of the workshop were to examine current procedures used by the Corps for inspection and emergency repairs by presenting case studies and experiences and follow up these discussions with suggestions and recommendations for improvement. Ongoing ERDC research and development in the areas of inspection and emergency repairs was also presented. Brainstorming sessions were conducted to

document ideas for innovative designs for emergency closure structures and techniques and equipment that could be used to help remove barges lodged against dams.

2 Workshop Agenda and Attendees

Final agenda

The agenda for the workshop was revised several times due to changes in presenters' schedules and last minute conflicts. The agenda showing the topics presented at the workshop is shown in Appendix B. Three technical sessions were presented. The General Session provided HQUSACE's outlook for navigation along with pertinent topics related to navigation. The Inspection Session was held on the afternoon of 18 April and the morning of 19 April, and the Emergency Repairs Session was held on the afternoon of 19 April and the morning of 20 April.

Workshop attendees

A list of the people who registered for the workshop is shown in Appendix C. Over 80 people registered, and, of those, about 75 percent were from District and Division Offices, 15 percent from ERDC laboratories, and 10 percent from industry. Personnel from the Great Lakes and Ohio River, Mississippi Valley, South Atlantic, Southwest, and Northwest Divisions participated in the workshop with 14 Corps Districts represented. Five of the laboratories participated in the workshop and seven industry representatives registered for the workshop. The District and Division Offices presented half of the technical sessions, and the ERDC laboratories and industry presented the other half. A photo of the attendees present on the last morning of the workshop is shown in Figure 1.

Figure 1. Workshop attendees.

3 Technical Sessions

Web site

The presentations for the workshop were converted to pdf files and placed on the Coastal and Hydraulics Laboratory (CHL) Web site at http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ARTICLES;679 for viewing. The discussion and comments made after most of the presentations are provided herein.

General session

Future outlook for Corps navigation work

Mike Kidby, HQUSACE, presented this topic. The items discussed in the presentation are shown in bullet form below. Refer to the Web site for additional information.

- Navigation and Operations Community of Practice contacts
- Corps mission
- System reliability
- Risk and reliability
- Navigation assets and age
- U.S. Harbors
- Strategic ports
- U.S. fuel – taxed waterway system
- Major inland navigation studies
- Navigation benefits
- Issues or challenges
- FY 06 budget by business line
- FY 07 budget by business line
- Operation and maintenance (O&M) business functions in FY 07 President's budget
- Navigation O&M budget
- Trends – ships

- Future needs in shipping
- Outlook for increased trade
- Future freight demand
- Seeking solutions
- Bookmarks and Web sites
- Funding challenge.

Discussion followed Kidby's presentation and is summarized below.

Discussion concerned the A76 issues and outsourcing and whether the navigation industry is aware of all the impacts and possible consequences. There are still some uncertainties dealing with outsourcing and nothing will happen in FY 06. Issues concerning the outsourcing have been pushed back to FY 07.

There was also discussion concerning damaged structures and antiquated shipping laws. There may be a need to develop new laws to assist in repairing structures damaged from navigation accidents. The shipper's responsibility may need to be looked at further.

Navigation challenges in Mississippi Valley Division

Jim Hannon, Mississippi Valley Division (MVD), presented this topic. Discussion points are shown below:

- MVD navigation structures
- Structure condition
- Dewatering bulkheads
- Bulkheads and slots
- Aging facilities
- Decreasing risk – Improving reliability.

Navigation Systems Research Program

Jim Clausner, CHL, and Program Manager for the NSRP, presented an overview of the NSRP. Discussion points are listed below:

- Research progress/completed efforts
- Program structure
- Significant accomplishments
- Inland Navigation Focus Area
- Inland Hydrodynamics Work Area
- Inland Infrastructures Work Area
- FY 06 opportunities for industry input
- Asset Management Work Area
- Dredging Operations Technical Support Program (DOTS).

Engineering reliability analysis for prioritizing investment decisions

Larry Dalton, Louisville District, presented this topic. Key points of interest from his presentation are shown below:

- Existing system of Ohio River Locks and Dams
- Ohio River plan and profile
- Ohio River project details
- Ohio River Mainstem Systems Study (ORMSS)
- Engineering reliability analysis
- Forecasting the future
- Introduction to systematic evaluation
- Engineering reliability integration
- Typical Ohio River main and auxiliary locks
- Lock chamber closures
- Assessment of needs – capacity and traffic
- Economic impacts of main lock closures
- ORMSS economic impact
- ORMSS reliability integration
- Selection of critical components
- Types of components
- Non-time-dependent components

- Non-time-dependent model details
- Time-dependent components
- Current condition of structure
- Advanced modeling for realistic failure modes
- Modeling for field limit states
- Time-dependent reliability modeling
- Model outputs and integration with economics
- Optimized timing of component replacement
- Example of reliability-based economic evaluation
- Greenup Locks – main chamber miter gates
- Deterioration of Ohio River miter gates
- Plan development
- Ohio River Navigation Investment Model (ORNIM)
- ORNIM analysis of capabilities
- ORNIM reliability output
- ORNIM economic analysis
- Recent applications
- Studies from ORMSS
- New reliability guidance based upon ORMSS.

Standardization of lock design

Jeff Stamper, St. Louis District, presented this topic. Discussion points are listed below:

- Workshop theme questions
- Future problem solving considerations
- Lack of documentation (universal problem)
- Navigation and Ecosystem Sustainability Program (NESP) navigation locks focus
- Introduction to NESP
- NESP vision statement

- Ecosystem restoration implementation
- Navigation project costs
- Navigation projects FY 05 and FY 06 Preliminary Engineering and Design (PED) budgets
- Upper Mississippi River (UMR) new locks
- Implementation timeline
- Lock system plan and funding needs
- NESP lock design
- Lock design objectives
- Design Product Delivery Team (PDT) and Quality Control (QC) measures
- Standardization tools
- Standardized concept development
- Standard decision making criteria comparison matrix
- Standard matrix for alternatives comparisons
- Lock design concept: locks 20 through 25.

Some discussion about Value Engineering (VE) followed Stamper's presentation. VE is important and needs to take place at a point in the design process where the ideas can be incorporated into the project design. There were some who think that a VE study after PED is completed is too late to incorporate good recommendations. A question was raised about the impacts to navigation during construction. The construction time will affect the economic benefits, and there is some uncertainty about the long-term effects of this and increased traffic on the waterway.

Infrastructure asset management

Dr. Sandra Knight, CHL, temporarily assigned to HQUSACE, presented the current efforts in the Corps concerning asset management. Points of discussion are listed below:

- Why asset management? - high level
  - Corps owns lots of stuff
  - At least 1000 coastal structures
  - Real value – no one is sure, trying to roll up.

  - Two drivers – strategic plan, infrastructure life cycle mgt – 2012
  - Executive order – federal – real property – strict rules and goals
- What is asset management (engineer perspective)?
  - Start with initial investigations – level of service, 50-year life expectancy, have a maintenance plan
  - Poor maintenance, shortened life, major investments, rehabs, etc.
  - What, when, how to maintain, extend life, and make smart investments
- What is important?
  - Outside experts, agencies
  - Lack of standardization
    - Definitions, what is asserts
    - Standards on inspection, engineering design
  - Project conditions
    - Condition assessments.
  - Risk and uncertainties
    - What are consequences – how do we decide what to invest in?
  - BL – specific – Nav, F&C, Hydro
- What will we achieve? The vision
- Life cycle management (LCM), business process model, infrastructure assessment and evaluation, data integration asset management plan
- Conceptual pyramid
  - Base is data – must have good data, always cut that short
    - "We can't afford the data" argument
    - Fundamental piece
    - Lean Six Sigma – new Corps Mantra, Technical Quality Management (TQM), re-engineering the Corps
      - Basic Principles, good data
- LCM – How does it work?
- What does Office of Management and Budget (OMB) expect?
- Executive Order 13327
- ERDC vision
- Who will execute?
  - HQ – put under Ops, Jerry Barnes

  - AM central – five to six people detailed or assigned to HQ making the road map
  - Team is setting up road map
  - Real execution at field level
- Who are they?
  - Dam safety
  - Levee
  - CISP
  - Databases – OMBIL, RecBest
  - Lots of effort, have aspect of AM
  - Hook those together
  - Internal and external teams
    - Have Division step out to lead piece
    - Charles Krahenbuhl – FEM lead in hydropower
    - Steering Committee – HQ, Assistant Secretary of the Army for Civil Works
  - Senior leadership committed, not just because OMB
- Condition assessment
  - Buy down consequences, buy up services
  - Not one size fits all
  - Simple to complex – screening to Monte Carlo
  - Multiple BL
  - End goal – hard part – multi-purpose projects
- Frequency of inspection in years
  - From PIANC
    - Problem – budgets are tight
- Risk map example
- HydroAMP – FEM/MAXIMO
  - HydroAMP risk and reliability tool – help to make investment decisions
- Condition assessment piece (most technically complicated)
  - Another OMB 9 (PART)
  - Learn from existing activities
  - Test drive with Great Lakes and Ohio River Division
  - Test drive with stakeholder
  - Last bench mark – how good is this – compare with industry, other
    - NPS, Bureau of Reclamation, hydropower

- Challenges
  - Standardization – same language
  - Data inventory – big push in HQ
  - Disposal – this quarter – initial list of things that are excess
    - Be creative – OMB thinks of buildings
      - Olmstead is replacing 52 and 53
      - Some buildings at Waterways Experiment Station
  - FEM/MAXIMO
    - Charter, Project Management Plan, team players – pilot study
    - How do it in Flood Control, Nav, Rec – well used in hydropower, must make sense for other BL
  - Risk based assessments
  - Life cycle management staying green
- Rainbow
  - Goals – feel good
  - Operate smarter, smoother
  - Incorporate into business processes
  - Help with budget
    - Reasonable set of tools, science based
    - More sense to Corps upper management and Congress

Q: Understand, economize, put money back into, it costs money to dispose (tear down and get off books, it does not generate funds)?

A: An example of trying to dispose of property was when the Corps gave the state of WI Fox River Locks. The state wanted the project in mint condition and wanted the Corps to pay to maintain the project. The Corps decided to keep the project.

Comments: OMB has final rule on disposal. The State Department gave presentation on disposing of property but they only have embassies. Everything the Corps owns is a structure, building, or land.

Inspection session

Robotics for Corps civil works applications

Dr. Jim Lever, Cold Regions Research Engineering Laboratory (CRREL), presented this topic. Points of interest from his presentation are listed below:

- Project description
- Research objective
- Approach
- Products
- ERDC – CRREL role
- Case study approach
- Mobile District projects
- Millers Ferry Lock
- Jamie Whitten Lock
- Other case studies
- Sault Ste. Marie in Detroit District, Seattle District Projects
- Chelan County Public Utility District
- Needs – Preliminary.

Q: How does the robotic unit handle currents?

A: The unit begins to have difficulty with currents greater than 3 knots. With higher currents, CRREL has had better success with a diver and hand-held camera.

Q: What other measurements besides sonar and visual images can the unit be used for?

A: The unit could be equipped to measure velocity, temperature, pressure, and pH.

Comment: It appears this unit could be beneficial for making baseline measurements or maps of interesting areas and placed back in these areas at the same location periodically to monitor changes in measurements or condition of the structure.

Q: Could the unit be used to develop accurate maps of stilling basin conditions to identify areas of scour or erosion instead of using divers?

A: Dr. Lever felt the unit was capable of providing this information.

Q: Can the unit determine scour depth?

A: Not sure, the unit probably needs some higher precision equipment to investigate scour depths.

Current inspection policies for hydraulic steel structures

Dr. Joe Padula, Geotechnical and Structural Laboratory (GSL), presented this topic. Discussion points are provided below:

- Terminology – Fracture critical member (FCM), Non-destructive examination (NDE)
- Inspection requirements for hydraulic steel structures (HSS)
- ER 8157 types of inspection
- ER 8157 periodic inspections
- ER 8157 initial FCM inspection
- ER 8157 damage inspection
- ER 8157 frequency of inspection
- EM 6054 structural deterioration
- Weld discontinuities
- Profile, volumetric, and planar defects
- NDE: how to look
- Purpose of NDE
- The big five NDE methods
- Visual examination
- Penetrant examination
- Magnetic particle examination
- Ultrasonic examination
- Radiographic examination
- Examination vs. discontinuity
- Acceptance criteria
- Fitness for purpose
- Critical areas – where to look

- Preparation
- Critical areas for fatigue and fracture
- Critical areas – tainter gates
- Trunnion assembly – thick plate weldments
- Critical areas for lift gates
- Critical areas for miter gates
- Field inspection comments
- Structural instrumentation.

Comments: Discussion after Dr. Padula's presentation covered existing codes, Engineer Manuals, interpretation of AWS D1.1 (a welding criteria), tubular connections, FCM members, and requirements for diver's inspection.

Concrete condition survey methods in the Rock Island District

Tom Mack, Rock Island District, presented this topic. Items discussed during his presentation are listed below:

- Concrete deterioration – functional issue
- Safety
- Damage to tows
- Concrete reliability
- Concrete cost
- Concrete condition report
- History review
- Concrete condition survey
- ACI 201.1R – EM 1110-2-2002
- Concrete distress mapping
- Photo logs
- Typical concrete distresses
- Obtaining cores
- Lab testing

- Petrographic examination
- Petrographic analysis results.

Q: Is the inspection method used in Rock Island standard in MVD?

A: Not sure, St Paul uses these methods but a lot of same techniques are probably used in the other Districts.

Q: How many people are involved in an inspection?

A: Usually two to three people including a materials engineer and a student aid or summer hire.

Q: How long does it usually take for concrete distress mapping?

A: Generally requires a couple of days.

Mel Price Locks and Dam miter gate inspection

Tom Ruf, St. Louis District, presented this topic. Discussion points are provided below:

- Auxiliary lock downstream miter gate
- Damage to miter gate
- Initial inspection
- Overall gate distortion
- Local damage – miter ends
- Damage to gate anchorages
- Primary anchorage
- Secondary anchorage
- Miter block – Illinois (IL) leaf
- Timber fender – Missouri (MO) leaf
- Diagonal buckling failure
- Cracked gusset – IL leaf
- Failed operating struts

- Operating arm failure tube
- Operating strut failure – IL and MO leaves
- Gouged operating strut
- Failure tube bolts
- Inspection of leaves on gate barge
- Surveying leaf
- Survey results – IL and MO leaves
- Inspection by manlift
- Deformed diaphragms
- Inspection with leaves in horizontal position
- Crack at diaphragm flanges
- Crack in girder flanges
- Inspection of repairs
- UT inspection of diagonal gusset
- Strut arm at service base welding
- MT inspection of strut arm at shop
- UT inspection of strut arms
- UT testing of repaired cracks
- Diagonal modification
- Lower diagonal gusset
- Stress relieving diagonal gusset
- Top and bottom end diagonals
- Gudgeon hood casting
- Casting weld repair defects
- Locks 27 – miter gate inspection and instrumentation
- Locks 27 auxiliary lock miter gates
- Cracks in girder flange
- Instrumentation of typical connection
- Instrumentation results

- Locks 27 – Main lock Jan 2003
- Failed diagonal rods
- Instrumentation of diagonals
- Instrumentation results at Locks 27
- Rope access inspections
- Clarence Cannon Dam – spillway tainter gates
- Locks 27 miter gate
- Kaskaskia Lock and Dam tainter gate
- Carlyle Dam tainter gate

Q: Was there any damage to the pintle from the accident that occurred at the Mel Price auxiliary lock?

A: Yes, and these will be discussed in the presentation on the emergency repairs session.

Comments: Damage to structure should be inspected as soon as possible before evidence disappears. Write notes on damaged areas so pictures give more complete information.

Methodology for assessing concrete condition for rehabilitation at LaGrange Lock

Dr. Anne Werner, Rock Island District, presented this topic. Discussion points are shown below:

- Inspection – Repair/Rehab – Justify Funding – Fund?
- Inspection of LaGrange Lock
- Justify funding
- Rehabilitation – improve reliability
- Rehabilitation – economic analysis
- Economic analysis must include probabilistic life-cycle simulation
- Expert elicitation
- Other methods for life-cycle analysis
- LaGrange Lock expert elicitation workshop

- Elicitation process
- Elicitation results
- Applicability of expert elicitation – Lock 19 and Lock and Dam 18
- Summary.

Q: Where was expert elicitation workshop held?

A: Rock Island District.

Q: Did Industry participate?

A: Yes.

Comments: When expert elicitation is used, open minded participants who are good communicators are needed. Instead of expert elicitations, condition indices/ranking could be used.

Evaluation of wire rope tainter gates, in accordance with EM 1110-2-2702

This topic was presented by Shahir Safi, Kansas City District. Discussion topics are listed below:

- Tainter gate terminology
- Vertical rib, girder, strut, downstream vertical truss
- Generating 3D model in Microstation for export to STAAD
- Horizontal girder and vertical rib modeled with same center-line and eccentric stubs
- Building 3D frame model in STAAD
- Microstation model exported to STAAD
- Assignment of section properties
- Specification of structure members
- Trunnion support condition
- Wire rope against skin plate
- Wire rope drum assembly support modeled as pin
- Engineer Manual Load 1 – gate sitting on sill

- Engineer Manual Load 2 – gate lifting off sill with two hoist cables
- Hydrostatic load
- Side seal load
- Engineer Manual formulae for side seal load
- Side seal load in STAAD
- Trunnion friction movement
- Modified EM 2702 load case 1 – interaction values
- Modified EM 2702 load case 2 – interaction values
- Member with highest interaction value
- Controlling member without trunnion friction moment
- Controlling member without trunnion friction moment and side seal
- Analytical check of model.

Q: What was the coefficient of friction used in analysis for the trunnion?

A: 0.3.

Q: What is the coefficient of friction for the trunnion with lubrication?

A: 0.15; however, 0.3 was used in the analysis to account for possible rusting conditions.

Q: Has anyone done research on trunnion friction since there are so many uncertainties and the values are crucial for proper structural analysis?

A: The Sacramento District has looked into this issue since the Folsom Dam gate failure.

Jamie L. Whitten Lock and Dam culvert repair and inspection

Harry Stone, Mobile District, presented this topic. Discussion points are provided below:

- Whitten Lock culvert repair – Aug 2001
- Jamie L. Whitten Lock and Dam details
- Bottom longitudinal floor culvert system (“H” or tuning fork system)

- Concrete erosion in filling/emptying system culvert
- Repair procedure
- Periodic underwater inspections
- Underwater inspections using remotely operated vehicle (ROV)

Q: When was project first dewatered?

A: The lock went into operation in 1985 and had not been dewatered until 1996 when damage was identified.

Q: Why did concrete erode?

A: Faulty concrete was suspected. Concrete placed during questionable temperatures, good possibility the concrete might have frozen.

Q: What type of grout was used for the repair?

A: Chemtrex, Masterflow 928.

Q: How long was the lock closed for the repair?

A: 21 days.

Q: How often is the culvert inspected with the ROV?

A: Every three to six months.

Q: What type of data is collected with the ROV?

A: Digital video and sound. Has capability to show individual frames to help show areas of concern.

Q: What is the status of the repair?

A: Repair is holding up well, only minor deterioration has been detected. Inspection frequency is now six months.

Q: When using the camera on the ROV unit, how far from the culvert wall is the camera?

A: The camera is between 1 and 2 ft from the structure it is imaging. The unit has some buoyancy control and can be raised and lowered as needed.

Q: What is alternative to ROV?

A: Divers.

Q: How much do divers cost?

A: $35,000 per week.

Q: Is it difficult to detect damaged areas?

A: Once you know what you are looking for, it is much easier to detect on images.

Comments:

Concrete problem description – Half of concrete was missing in roof of culvert. The problem was located at the waterstop. A new waterstop groove was installed with diamond tip chain saw.

Repair Procedure – ERDC employees from GSL, Billy Neely and Brian Green, assisted in the grouting operations. The culvert had to be contoured to prevent air entrainment.

Periodic inspections

This topic was discussed by Phillip Sauser, St. Paul District. Points of discussion are listed below:

- Periodic inspection – embankment/riprap, concrete condition, steel condition, machinery operation
- Other inspections – instrumentation, soundings, diving, HSS, bridges, dewatering, site personnel, condition index
- Issues – safety, function, technical expertise, reporting/documentation
- Reports/documentation – instrumentation, soundings, other inspections, PI report

- Report purpose – record of inspection, historical document, decision document
- Data management – inspection reports, design data, evaluations, construction documents, test reports, foundation data, O&M manual, EAPs
- Data management – database systems, standardized, accessible, regionalization, Web-based
- U.S. Army Corps of Engineers Bridge Inventory System – CEBIS
- System structure – inventory data, inspection notes, photos and sketches, quality control/quality assurance (QC/QA), report approval, inspection reports.

Q: Are professional engineers required to go out with inspection teams?

A: Prefer personnel with appropriate experience and background.

Q: How does St. Paul District (MVP) handle data bases?

A: MVP generates a lot of data and information at present for its projects, but it is not in a very usable form.

Q: Where did mandate come from to inspect bridges?

A: Federal Highways.

Q: Where is data located for bridge inventory system?

A: ERDC and everyone has view access.

Q: What is the estimated cost for a periodic inspection?

A: $30,000 to $50,000 depending on project needs.

Q: Any way to capture economic benefits from inspections rather than using costs generated due to failures?

A: Good idea, not sure if this has been attempted.

Q: Is anyone working on a database management system for HSS?

A: Don't think so due to shortage of funds, but this needs to be done and should be done smartly.

Q: What is the estimated time and cost to develop the bridge inventory system?

A: Three years and $50,000.

Q: How many people were involved in developing this system?

A: Phil Sauser was the main developer and used a lot of information supplied by the bridge industry.

Response: Little Rock District performs gate inspections on every gate whereas St. Louis District often inspects one tainter gate and one roller gate per project periodically.

Comment: Kansas City District is using or looking at existing software for database management Project Wise.

A high resolution acoustic camera for inspection of underwater structures

James Evans, Information Technology Laboratory (ITL), presented this topic. Evans showed several video clips of images recorded using the acoustic camera. Topics discussed during his presentation are shown below:

- Dual frequency identification sonar – (DIDSON)
- DIDSON specifications
- Inspection of underwater structures
- Field demonstration – March 2002 Olmsted Lock and Dam, Cape Girardeau
- Underwater imaging system
- Field demonstration – Yazoo River
- Underwater inspection of gates using ROV
- Initial acoustic camera deployment system
- Underwater positioning

- Structural applications – outlet works, spillway conduits, toe drain systems, penstocks, pipelines, dam faces, gates
- Other applications – identification of endangered species, fish species, hydrilla plants
- Project objectives
- Summary.

Q: How does sediment affect imaging?

A: The camera can image well in turbid water although if clouds of sediment are stirred up during the deployment, the imaging will not be as good. There are some sensitivity controls to help with this problem.

Q: What particle size affects the imagining?

A: The density of the particles may affect the imaging as well as the particle size.

Q: Where can one find out more information about the camera?

A: DIDSON has a Web site.

Q: Is there a company that sells the camera?

A: Yes.

Q: What does the camera cost?

A: The camera costs around $75,000 – $80,000.

Comments: The camera was originally developed by the Department of Defense to help identify terrorists swimming. It was developed by Applied Physics Laboratory and has many areas of application. There is a need to develop optimum deployment methods because the camera is sensitive to movement. The camera imaging can be compared to looking at newspaper with a microscope. It is difficult to locate where you are. The DIDSON camera has an acoustic lens for focusing, D-A converted to improve image, resolution in mm range at short distances, 96 elements, and a frame rate of 20/sec.

Numerical evaluation of stress intensity factors: J-integral approach

Dr. Guillermo Riveros, ITL, gave this presentation. Topics of interest during the presentation are shown below:

- Problem description
- Objectives
- Fracture mechanics and the application to finite elements
- Modes of fracture
- Implementation of fracture mechanics in finite elements
- J-integral
- Numerical solution of infinite plate with edge crack
- 3-D finite element analysis of miter gate with multiple cracks
- Miter gate experimental evaluation
- Conclusions
- Recommendations and further research.

Q: What software is used in computations?

A: Abycuss that runs on 64 bit Windows machine with Linux operating system.

Comment: A data base for gates is a good idea, and it should contain materials properties and be tied into an inventory data base.

Ultrasonic measurement of tension in steel components of civil structures

Dr. Michael McInerney, Construction Engineering Research Laboratory (CERL), presented this topic. Discussion points in the presentation are listed below:

- Project overview
- Project application and benefits
- Ultrasonic basic theory
- Ultrasonic properties of structural materials
- Longitudinal and shear waves

- Transmission of ultrasound at interfaces between materials
- Reflection of ultrasonic waves
- Ultrasonic beam spread from a sensor
- Derivation of ultrasonic tension measurement equation
- Development of a simulator
- Setup for simulating echoes inside a plastic block
- Comparison between simulation and reality for a plastic block
- Setup for simulating echoes inside a steel rod
- Comparison between simulation and reality for a steel rod
- Using ultrasound to obtain tension measurements
- Measuring tension by using the simulator
- Measuring tension by using a unique dual mode sensor
- Moving from theory to field
- Block diagram of prototype instrument
- Laboratory verification of theory
- Field verification of technique
- Conclusions and future work.

Q: Can one get a reading on the tension in an anchor rod rather than knowing the tension when the rod breaks?

A: Yes, this is possible with this technique.

Q: When will the equipment be available for field use?

A: Probably by the end of the summer, but help and support are needed to conduct some calibration with material properties.

Q: Can the equipment be used to measure tension in rods with threaded ends?

A: If the rods are large, it should be okay, but the threads may have some effect for smaller rods.

Q: Does the length of the rod have a significant effect on the capability of the equipment? Some rods used on spillways anchoring are long. At one project, the rods were 46 ft long and broke 1 ft from the end.

A: The instrumentation has the capability to generate high energy levels and should work for long rods.

Introduction to TOFD & phased arrays industrial application

Randy Scheib, RD Tech, presented this topic. Discussion points in Scheib's presentation are provided below:

- What is ultrasound?
- Properties of sound waves
- What is an ultrasonic transducer?
- What is TOFD?
- Time-of-Flight Diffraction (TOFD)
- TOFD signals, history
- Data visualization
- Near surface crack
- Incomplete root penetration
- Technique description
- Phased array (combined scan)
- Technique advantages
- Introduction to phased array
- Phased array definition
- Key concept
- How phased array works
- Design parameters of phased-array probes
- Beam focusing, steering
- Phased-array probes
- Focal law
- Pulse-receive physics

- Electronic scanning
- Illustration of sectorial scanning
- Sectorial scans
- Sectorial scanning animation
- Schematic representation of dynamic depth focusing
- Dynamic depth focusing animation
- Portable phased-array applications
- Construction welding: inspection of small diameter austenitic piping, fillet welds
- Construction welding: sample crack and S-scan image
- Omniscan for pipeline welds
- Bolts – PA sectorial scan
- Road arm spindles/struts
- Component testing: thread inspection
- Aerospace: landing gear inspection, laser weld inspection, composite inspection, T-joint composite, aluminum to aluminum bond
- Additional applications
- Summary.

Q: What type of turbine was the turbine root inspection done on?

A: GE.

Q: What size crack were you trying to detect for the turbine example?

A: Microns.

Q: Are there any regulations for becoming certified to conduct inspections?

A: Yes, the company does the training and gives one certification.

Q: Is the unit only for the shop or do you also have a field unit?

A: Both, large units are available. They have new electronics and can still use motion control devices.

Q: Can the unit be used to determine pre-stressing?

A: Yes, the ultrasonic techniques are applicable.

Structural instrumentation and monitoring

Bruce Barker, ITL, presented this topic. Discussion points are provided below:

- Why instrument civil works structures?
- Why don't we?
- Sensors and measurement options available
- Example of structural instrumentation projects
- Trunnion anchorage testing Sep – Nov 2005, Canton Dam, Tulsa District
- Canton Dam pier 15 data
- Canton Dam pier 16 data
- Long-term monitoring instrumentation installed at John Redmond Dam
- Trunnion friction measurement evaluation at Strom Thurmond Dam, GA (Savannah District)
- Trunnion friction measurement concept
- Greenup L&D miter gate instrumentation Sep – Nov 2005 (Huntington District)
- Greenup Lock miter gate
- Cracking at reinforcement gussets
- Damage to reinforcement flanging
- Cracking around pintle casting
- Out of plane deformation of the thrust diaphragm
- Miter gate repairs
- Gate instrumentation – strain gage locations

- Strain gage installation
- Cable protection
- Data collection
- Stain data – S2 gages
- Example of a geotechnical instrumentation project
- Carters Reregulation Dam expansive concrete after action review (AAR) (Mobile District)
- Carters Reregulation Dam instrumentation locations
- Carters Reregulation Dam borehole extensometers
- Modified relative block movement devices (RBMD) for automated displacement measurement in longitudinal axis
- Light Detection and Ranging (LIDAR) survey of the structure
- Point cloud rendering of Carters Reregulation Dam
- CloudWorx software
- Advance in technology for structural monitoring programs
- The future in long-term monitoring instrumentation
- Sensametrics – wireless structural monitoring
- Sensametrics decision support software
- Summary and conclusions.

Q: Is there information on trunnion arm friction computations?

A: Yes, Carter Smith from Savannah District did the calculations for trunnion anchorage testing.

Q: Is this monitoring program tied in with Eric Halpin and the Dam Safety Risk Assessment program?

A: Not at present, but maybe should be.

Q: Is there any information on trunnion friction?

A: Periodically, the friction is monitored at some projects.

Q: Is there a data management structure?

A: Need support and funding to perform long-term monitoring to obtain data and set up databases.

Comment: Several trunnion arms at a project in Louisville District are not taking grease. This project might be a candidate for the Monitoring of Completed Navigation Projects (MCNP) research program.

A small research work unit would be beneficial to optimize sampling needs from an engineering and operations perspective. There is a need to know trunnion friction on many projects. Dr. Guillermo Riveros indicated this should not be very difficult. With the proper instrumentation, one can determine the appropriate loads on the gate and extract the trunnion friction values.

The MCNP program may be a good avenue to select a project, instrument the project, collect the desired baseline information, and then monitor periodically. Using the laser scanning equipment and strain gages mounted on the gates, useful information can be determined concerning the gate performance. Bruce Barker indicated that the submersible gates at Markland and JT Meyers projects had been instrumented with accelerometers, strain gages, and pressure gages.

In regards to data collection and management for gates, Mike Kidby suggested contacting Eric Halpin with the Dam Safety Assessment program for ideas and guidance. It may be helpful for Eric Halpin and Dave Schaaf to meet with Bruce Barker to have further discussions.

Dale Miller indicated that the amount of repairs can be reduced by instrumenting and monitoring projects and incorporating standards. Bruce Barker suggested that the costs for accomplishing this are modest.

High definition surveying

Mike Harvey, Leica Geosystems, presented this topic. Discussion points are provided below:

- Time of flight scanner
- Phase-based scanning systems

- Laser sweeps over surface
- Points are recorded
- Measuring technique is called LIDAR
- What LIDAR is: light detection and ranging
- What LIDAR is not
- Data acquisition options: 4,000,000 p/hr
- What is high definition surveying (HDS)?
- Why use HDS?
- Where HDS is best used
- Carters Dam as-built survey using high definition laser scanning
- Horizontal and vertical control
- Existing control used
- Control network
- GPS network
- Convention survey vs. scanner survey.

Q: What was the contract cost at the Carters Dam survey?

A: Don't know.

Q: Was survey done from a plane?

A: Done from ground with seven setups.

Q: What is cost of laser scanning equipment?

A: $145,000, includes training and software.

Q: Can you use to survey under water?

A: Water would have to perfectly still and clear.

Q: What is accuracy of survey?

A: Plus/minus 3mm, with excellent overlap.

Q: Is unit available through GSA?

A: Yes.

Q: How close to a structure can you be and still survey?

A: As long as the instrument can turn, you can obtain data at 1 m, maximum distance is about 750 ft.

Comments: Time of flight scanner – sweeps the scene. Pulses 1,800 points, 3-D space, per second, can also take a digital picture.

Phased scanner – laser always stays on, scans 500,000 points per second.

Records distances, can drape photo over the points.

Format – put into Microstation to get IGIS.

Point cloud, 3-D dot matrix of reality.

LIDAR – not a substitute for a total station.

Can put point cloud into CAD package – CloudWorx – AutoCAD, Microsoft.

HDS – best used for bridges, roads, structures, and dams.

PDT – Carters Dam as-built survey, 14,000,000 points.

At present, software can handle 3 billion points, next year 50 billion points.

Innovative technologies for condition assessment and monitoring of concrete

Dr. Richard Haskins, ITL, presented this topic. Discussion points are provided below:

- Concrete NDT is needed for many reasons
- Sounding and visual inspections are the standard for most inspection programs
- Instrumentation components for soundings (digitizer, impactor, sensor)
- Resonance-based systems
- Ultrasonic pulse velocity
- ERDC finding – ultrasonic through transmission
- Tomographic imaging (CAT – Scan)
- Eleven axis immersion scanning system
- Ultrasonic B-scan of an 8-in. concrete bridge deck
- Split spectrum processing
- Common difficulties testing large concrete structures
- Partial plan for condition monitoring and assessment research work unit
- Need tools for improved quantification of surface damage/ deterioration
- Low cost topography
- Conceptualized system
- Non-linear resonance spectroscopy.

Q: Can you locate reinforcement in concrete?

A: Magnetometer can be used to determine both diameter and depth; radar can also be used.

Q: What would be considered a bad material?

A: It depends on the correlation of the velocities and the proportion of amplitude to signal strength. We would need to develop correlations for the site being investigated.

Q: Is this applicable under water?

A: Acoustic signals work well under water.

Currents in lock approaches

Michael Winkler, CHL, presented this topic. This presentation leads into the emergency repairs session. Discussion points are shown below:

- Lock currents workshop was help at ERDC in March 2006
- Workshop participating groups – Corps, industry, Coast Guard, NOAA
- Schematic of outdraft at lock approaches
- Tom Bevill Lock and Dam Field Study (MCNP)
- Time lapse camera locations
- Multibeam survey of upper approach and guard wall
- Acoustic Doppler Current Profiler (ADCP) survey of upper approach
- Prototype tow track data
- Float data to determine currents
- Tom Bevill physical model study
- Horizontal ADCP mounting location
- Velocities displayed on IENCs.

Q: Was wall length investigated in studies?

A: Yes, but a more economical solution may be providing more information to navigate with.

Emergency repairs session

Repair of Quoin Seals at Hannibal Locks and Dam

Jim Fisher and Dave Sneberger, Pittsburgh District, presented this topic. Discussion points from the presentation are provided below:

- A time line of what happened
- First quoin block failure 15 September 2005
- First emergency repair 15-16 September 2005
- Hannibal Locks and Dam OR – Auxiliary lock valve repair
- LWEV tainter valve replacement

- Second quoin block failure 1 November 2005
- Second emergency repair 1-15 November 2005
- Inspection of other gates
- Impacts to operations
- Why it happened
- AAR analysis – Summary of contributing factors
- Future actions
- Things that enhanced success.

Q: What is the lift at Hannibal Locks and Dam?

A: 20 ft.

Q: What was the procedure for inspecting bolts at Hannibal?

A: The decision was made to replace bolts with stainless steel bolts, also replaced quoin blocks. The backing material was also replaced with zinc.

Q: Did you consider welding?

A: Some were welded.

Q: Did you consider carbon blocks?

A: Used stainless steel.

Q: How old is the Hannibal project?

A: 1973.

Q: What type of wearing compound did you use?

A: NORDBACK®. Have used BELZONA, but it is more expensive.

Q: Are there quoin blocks that don't require backing material?

A: There is a wedge type system available, but there can be problems with the stainless steel galling. The Louisville District (LRL) has a new design that they think will work well. Vanderbilt did a study with nine factors. The system can adjust as field conditions change. It is proposed to put this system in with the new 1,200-ft chamber at the McAlpine project. The design has features for quick change out and can take up many adjustments. There is much interest in quoin block design, wedges, and adjustments. An annual conference may be a good idea. Engineers at LRL can be contacted for additional information.

Comments: After an incident occurs, it is extremely important to document events. The timeline will be needed for reporting to others and you will refer back to this document many times. Suggest placing a large sheet on wall and immediately start recoding events. During the Hannibal incident, there were two official releases daily.

Belleville Locks and Dam barge accident

John Clarkson, Huntington District, made this presentation. Discussion points from the presentation are provided below:

- Barge accident 6 January 2005
- Description of accident
- Locations of barges against dam
- Aerial view of Belleville Locks and Dam
- Photos of barges against dam
- Salvager's equipment
- Installing pad-eye
- Pulling cables being installed
- Cutting beam and pile driver
- Lifting barges from downstream
- Cutting torch operations
- Hydraulic shear – track mounted on a barge
- Divers cutting barge PEN 207
- First of five gates cleared after 17 days

- Removing wreckage downstream
- Rigging pulled out of last barge
- Installing sling under bow of barge AEP 8815
- Last barge – pulling with three towboats
- Lifting with project bulkhead crane and salvager's A-frame crane
- Lock reopened after 26 days
- Debris accumulation
- Loss of pool
- Exposed intakes
- Past accidents, Smithland Locks and Dam, Cheatham Lock and Dam, Pile Island Locks and Dam, Columbia Lock and Dam, and Maxwell Locks and Dam
- Need barge accident study.

Q: Is Belleville project founded on bedrock or piles?

A: Bedrock.

Q: Was there any damage to the dam gates?

A: Only cosmetic damage.

Comment: At Dam 2 on the Arkansas River, a 0.5-in. cable was used to cut through barges against the dam.

The barge accident blocked five of the eight gates. The gates could not be dropped. The costs were estimated at $5M per day. The loss of pool aided salvage operations. It is desirable to get equipment onsite as soon as possible before the pool is lost. When trying to use the track mounted hydraulic shear, the tracks slipped on the barge decks, and this method was not very effective.

Most of wreckage came out by pulling down stream. The lock was reopened 26 days after the accident. During the loss of pool, industry intakes were exposed. May be beneficial to perform a barge accident

investigative study to determine the number of modern era pool loss accidents and to find commonalities among accidents.

It appears the best way to plan for getting equipment to a project is to transfer over road. The integrated cutting beam with pile cutter seems to work well for removing barges.

Cannelton and Smithland, barges in dam gates

Pete Frick, Louisville District, discussed this topic. Discussion points are shown below:

- Barges in dam tainter gates – Cannelton, January 1991, and Smithland, April 2005
- Reasons for accidents and impacts
- Barges around piers
- High flows on river
- Loss of pool
- Options to clear barge from dam pier
- Preferred alternative: chop the barge in two
- Floating crane with chopping beam at Smithland
- Personnel in basket lowered from bridge
- Chopper beam lowered from the dam bridge
- Tainter gates or emergency bulkheads lowered onto barge
- How can we improve?

Q: Were divers used at Smithland?

A: No.

Q: Were there problems with scour due to the accident at Cannelton?

A: The foundation was not threatened.

Comments: The loss of control may be associated with drift in the river. If tainter gates can't be lowered, there is real danger in losing the upper pool. A primary concern in an accident is to maintain the pool.

Techniques to remove barges from dams need to be researched further. A chopper beam lowered from the dam bridge, dropped, or driven is a good idea, but is limited since there is no way to secure when the cutting is needed further upstream from gate bay slot. Research on guiding system combined with bulkhead crane is needed.

The Road Ahead – How can we improve?

This recurring issue of removing barges needs a well engineered, safe, and accepted approach. A structure and means of positioning already exist at many locations with the dam service bridges and bulkhead crane.

McAlpine Lock closure and emergency repairs

Pete Frick, Louisville District, presented this topic. Discussion points are provided below:

- Project overview
- Gate problems – gudgeon and pin anchorage, quoin blocks, miter blocks, pintle
- Cracked welds at pintle socket connection to gate
- Cracked welds across girder flange and Web
- Why are emergency repairs and lock closure necessary?
- Preparatory measures
- Public and industry coordination
- Repair planning and preparation
- Staffing
- Equipment and materials
- Scope of work
- Plate reinforcing repair overview
- Crack repair overview
- Web straightening and repairs

- Closing observations.

Comments: Ohio River projects have much commonality, and emergency repair guidance is needed in-place up-front. It was suggested to get industry involved and have an industry onsite coordinator. Also, it was suggested that PAO employees onsite help with media. Good documentation is needed since one will be required to tell the story many times. The documentation helps with the time line and the AAR.

John Day Navigation Lock emergency repair

Matt Hanson and Reed McDowell, Portland District, presented this topic. The points of interest discussed are shown below:

- Previous emergency repair experiences
- U.S. navigation locks
- Typical strain gage installation
- Repair challenges
- Current status
- Failed wire rope in upstream gate
- Upstream gate mechanism
- Wire rope failure mechanism
- Lock and gate damage
- Gate side buckled
- Broken welds, buckled beams
- Gate repairs
- Emergency operation of the lock
- Installation of repaired gate
- John Day monolith repair
- Lock monolith 8 – confirmed crack planes
- Main features of repair contract
- Monolith joint – pure epoxy injection
- Investigate/work prior to advertisement

- Outage issues
- Construction issues
- Capability/lessons learned.

Q: Are there high standards for weld repair procedures or are welders qualified?

A: Not sure.

Comment: Inca has weld repair procedures guidance.

Q: Was the gate that failed supported by a single wire rope?

A: It was supported by four cables.

Q: Were wire ropes replaced in a timely fashion?

A: Every 10 years.

Upper Mississippi spare gate system

Jim Wilson, Rock Island District, presented the spare gate miter gate system used in the Rock Island District. Discussion points are shown below:

- Spare miter gates
- Location map/field studies
- Mississippi River Project Office Lock
- Lock and Dam No. 14 and auxiliary lock
- Spare gate system
- Spare gate top section with section to be removed
- Attaching new section to top section
- Locks 2-10 gate details – St. Paul District
- Locks 11-22 gate details – Rock Island District
- Illinois Waterway Locks Peoria and LaGrange gate details – Rock Island District

- Locks 24 and 25 gate details – St. Louis District
- Weight of service gates
- Spare gate sections A-H
- "Quad Cities" gate lifter
- Testing the Quad Cities
- Quad Cities Lock 19 spare gate setting and removal
- MV *Bettendorf,* Quad Cities gate lifter, spare gate barge, and cargo barges
- MV *Rock Island* and tow
- Maintenance support
- Old River Lock miter gate replacement with Quad Cities gate lifter
- Gate changeout assistance at the Inner Harbor Navigation Canal Lock
- Mechanical dredging equipment
- Contact information.

Columbia Lock and Dam Ouachita River, repair of tainter gate strut arm damaged by barge impact

Ed Chisolm, Vicksburg District, presented this topic. Discussion points in Chisolm's presentation are listed in the following bullets:

- Aerial view of Columbia Lock and Dam with project details
- Depiction of barge accident in March 1997
- Identifying the problem: Remove two sunken barges, damaged and inoperable tainter gate, too much flow through the navigation pass, river forecast is bad news, and no heavy equipment upstream
- Using highway barriers to get project back in operation
- Schematic section of sunken barges against dam
- Diver rigging sling to lift barges
- A-frame cranes lifting barges
- Schematic of scour locations at navigation pass, guidewall, and upstream from dam
- Repairing scour with riprap

- View of damaged tainter gate strut arm
- Second barge flips on its side
- Heat treating damaged strut arm
- View of gate before and after repair
- Overall repair expense $1.25 million.

Mel Price Auxiliary Lock downstream miter gate repair

Tom Ruf, St. Louis District, discussed this topic. The discussion points used in Ruf's presentation are shown below:

- Project location
- Mel Price accident, 3 October 2004
- Example of miter functioning properly
- Gate leaves forced downstream from their normal mitered position
- Damage summary
- Damage to gate anchorage, failed operating struts, diagonal failure, damage to miter end leaves, pintle socket sheared off, bent and cracked pintle socket, pintle ball retainer sheared off, bottom seal damage
- Gate operating arm – failure tube
- Normal miter bloc position
- Gate control stations
- Magnetic proximity switch on gate
- Switches on machinery rack
- Modification of programmable logic controllers (PLCs)
- Miter gate sill
- Investigation report findings
- St. Louis District actions taken based on report recommendations
- Inspection main lock
- Multi-disciplined team
- Concentrate on critical activities
- Variety of contract instruments

- Gate repairs – cutting gate anchors, removing Illinois leaf, placing Illinois leaf on spare gate barge (sgb), guy cables installed, both leaves secured vertically on sgb
- Damage inspection
- Surveying damaged gate
- Survey results – Illinois leaf
- Convene panel of experts
- Conclusions from panel of experts
- Laying gates down horizontally, redesigned lifting beam, testing lifting device, installing lifting device, laying gate down, gate on support stands, leaf supported in deflected position, enclosing working area
- Heat straightening
- Support condition for checking straightness
- Structural repairs – revised strut arms and pintle sockets, welding strut arm at service base, modified bottom end diagonal, casting anchor bars and gudgeon barrels at Rock Island Arsenal
- Gate stops on miter sill
- Lifting repaired leaves vertical
- Installing lifting device
- Leaves in toaster for transport to lock
- Reinstalling gates
- Repaired Illinois gate in place
- Welding and boring gudgeon pin plates
- Installing Missouri leaf
- Repaired Missouri gate in place
- July 2005 Auxiliary Lock back in service.

Q: Do you have a light on the miter gate?

A: No, not required by PLC. There are two switches on the miter gate. One was not working and the other switch was reprogrammed for a special situation and was not returned to its original logic.

Q: Should another camera be used?

A: The operators do not depend on cameras; they depend on the logic in the PLC.

Q: Was the locking device on the gate working?

A: It was not working; the logic had been changed.

Comment: Lock 1 on the Mississippi River has a camera that looks vertically down at the gate. SAM has PLC systems, but still does a visual inspection on the gates. At the auxiliary lock, the control room is a considerable distance from the lower gate.

Modeling navigation conditions at lock approaches

Howard Park, CHL, presented this topic with the assistance of Dr. Richard Stockstill, CHL, and Dr. Mark Hopkins, CRREL. Discussion points are provided below:

- Modeling considerations
- Ice Harbor Dam streamlines
- Couple Discrete Element Model (DEM) capabilities with Adaptive Hydraulics (ADH) Model
- DEM structural capabilities with ADH flow solutions
- Recent products
- Guard wall designs – skirted guard wall, multicell guard wall
- Monongahela River Locks and Dam No. 4 – existing condition velocity vectors
- Lock downstream from river bend
- Bend effects on lock approach
- Computing outdraft from hydro model
- Computational modeling of ice and debris
- Problem: ice and debris accumulation at locks and dams
- DEM simulation of debris accumulation at Monongahela River Lock and Dam No. 4

- DEM/water interface
- Ice passage through a guard wall
- Debris passage through a guard wall
- Simulation of ice boom operation
- DEM simulation of logs and piers upstream from Monongahela River Locks and Dam No. 4
- DEM simulation of tow, logs, and piers upstream from Monongahela River Locks and Dam No. 4
- Flow patterns with solid guard wall
- Flow patterns with ported guard wall
- Example of well designed ported guard wall at Greenup Locks and Dam
- Example of 1200-ft floating guard wall
- Physical model laboratory results of velocity vectors in lock and dam approach
- Physical model laboratory results of tow tracks in lock and dam approach.

Q: Can you model wind in ADH?

A: Wind was not modeled in the simulations shown, but ADH has the capability to include wind.

Q: How big is the opening in the guard wall modeled to help flush ice and debris?

A: A 100-ft opening was modeled, but the opening size could be evaluated for the specific project conditions.

Comment: Pete Frick, LRL, thought there was a lock on the Kentucky River that had an opening in the guard wall.

Great Lakes and Ohio River Division's (LRD's) maintenance standard

Bob Willis, LRD, presented this topic. Discussion topics from the presentation are provided below:

- LRD sub regional navigation maintenance PDT
- Primary objective – develop LRD maintenance standard for navigation locks and dams
- Rate savings and tonnage as performance measures
- Equal risk of failure at all locks
- Rate savings and tonnage with impact, plus rate savings without impact
- Special considerations
- Regulation format – purpose, applicability, references, general policy, Appendices A-C in maintenance standard document
- Appendix A in maintenance standard document – LRD standard assessment and inspection
- Appendix A in maintenance standard document – Inspection team, procedure, dive inspections, lock dewatering intervals
- Appendix B in maintenance standard document – LRD risk assessment/assignment
- Appendix C in maintenance standard document – LRD process for identifying impact and prioritization for navigation locks and dams
- Impact based, non-impact based, and combined ranking of the importance of LRD main chamber
- Conclusions.

Q: Who can one contact for further information on LRD's maintenance standards document?

A: Dan Butcher, LRD.

Q: Are any other Divisions developing standards?

A: Mike Kidby indicated these were the first standards to be applied across regional boundaries.

Q: Is there funding for regional fleets?

A: Fleets are revolving fund facilities packaged within projects.

Q: What is driving fleet standardization?

A: Cost mainly, but there are other aspects. This will be similar to operation on demand. Most likely, operations in the future won't resemble operations today. From a budget perspective in the future, we will look at all fleets in a region as one fleet. The river Districts have large fleets and we will need to optimize budgets. An example would be that, in the future, Pittsburg District may come to the Greenup Locks and Dam project to help with a closure. If the Greenup closure gets rescheduled, another District may come if Pittsburgh cannot, and also closures could be done concurrently with cost savings to industry. This is a good way for the system to work. With adequate funding, this will work well, but with limited funding, one cannot always make the smartest decision.

Q: Do you have standardization for roving maintenance crews?

A: The staff is identical at each lock. There are differences in personnel on tributary projects. At some of the low tonnage locks, the operation is on demand. Many projects with high recreation use do not get needed personnel. At some of the projects on the upper Monongahela River, only two people are on duty, and some of the smaller projects in the Nashville District that do not operate all the time have no mechanics on duty.

Comments: Need to include diving inspections as part of the impact number for project comparison. If you have a low-use lock, you probably will not inspect as often. This technique allows one to compare a single lock chamber on Ten Tom, low tonnage, but high value product with a higher tonnage lock with low value product. The primary concern for District operations is to avoid unscheduled closures at high tonnage locks.

Periodic inspections are the main tool for developing maintenance budgets, including diving inspections. For navigation structures, the tainter gates are very important, 70 percent of movable steel is on the dam, not the lock. The amount of infrastructure maintenance will be important for the tainter gates. The window for working on tainter gates is limited since high flows restrict access.

Due to the age of many projects, we are starting to see hydraulic cylinders reach failure points. Looking at the cylinders from the outside, one can't

tell the condition. The direct connect cylinders are recommended for replacements.

HQUSACE is seriously considering the maintenance standards being developed in LRD as a standard for Corps-wide application. The Corps would then have a way to look at maintenance needs across the nation.

An issue LRD is addressing is setting up a standing team for gate changes. The team would have a quick change gate lifter and lifting beam for use on the 16 modern locks on the Ohio River. They would have the capability to change out a gate in 7 days, same upper and lower gates. The projects would have spares.

When Districts are studying new project developments, they make sure to evaluate economics of commodities that truck and rail cannot handle. For example, coal cannot be moved via truck.

Many projects are difficult to retrofit with instrumentation and remote control equipment. It appears infrastructure is not receiving much attention. Infrastructure needs will probably come full circle in the near future and projects with high benefits will start to receive more funding. The Europeans seem to have realized the importance of their inland waterway systems more so than the U.S. This is due largely to the condition of their roads and railways and the fact that they ship much containerized freight. With their large commodities, they have no other options but to use the waterways.

4 General Discussions, Recommendations, and Brainstorming

Comments during Open Session

At the end of the workshop, a general discussion was held to provide the workshop attendees a chance to voice concerns or make recommendations about issues discussed during the workshop.

One concern was if the Corps Navigation Lock and Dam projects need inspection techniques similar to the Dam Safety Program. Since that program has dealt with many of the issues concerning inspection, documentation, data collection, data management, and reporting, it may be beneficial for someone to look into this matter.

Another issue was the difficulties often encountered when working with as-built drawings. The drawings are usually old and difficult to obtain. Since scanning technology is much better today, it would helpful to have all the drawings scanned and placed in a central location where the information could be accessed by District personnel. A huge effort after Hurricane Katrina involved scanning pertinent drawings and documents. Personnel from ITL, ERDC, and the New Orleans District scanned enormous amounts of information and placed it in a data repository for use by officials involved in the study. Point of contact (POC) for this effort is Denise Martin, ITL.

Three-dimensional imaging may be more helpful for inspections in the future. The technology for high speed data transmission has improved and will allow Districts to move data as needed. There is currently some research being done at ITL using power line communications for improved data management, and this has shown promising results. Additional research would be beneficial in this area.

A proposal to improve data management techniques for use in inspections at navigation locks and dams may need to be put together. A draft for this proposal could be placed on a Web site to solicit comments from those interested in improving data management. The bridge inspection data management system presented by Phillip Sauser, St. Paul District, is a

good example to look at when putting a proposal together for inspections at navigation projects. Also, the Dam Safety Program has a Dam Safety Management Tool with 617 dams and would be a good model for a database. Suggest contacting Eric Halpin for additional information on this tool. Also, all Dam Safety Program Managers should be contacted for their input. An automated data support system that sends messages to designated offices or persons appears to be the best way to obtain useful information.

A comment concerning the composition of the workshop presentations was that there was minimal representation from the geotechnical concerns with inspection and emergency repairs. In subsequent workshops, this issue will be given more attention.

Recommendations from workshop

One of the purposes for the NSRP to sponsor this workshop on Navigation Lock and Dam Inspection and Emergency Repairs was to provide recommendations to Headquarters and Division offices with regard to inspection and emergency repairs. Several suggestions, ideas, and recommendations were discussed. The following bullets provide a summary of this information.

Inspection recommendations

- Suggest using ROVs more to assist with many types of inspections. They can also be outfitted with various types of equipment to obtain measurements that could be useful in long-term monitoring and condition indexing.
- A database management system should be developed to improve dissemination of information obtained during inspections. The system should have automatic messaging capabilities. HSS components should be a primary part of this system and should contain material properties and be linked with an inventory system.
- Additional research is recommended to determine appropriate values of trunnion friction to use in structural analysis of tainter gates.
- Investigation is recommended to determine capabilities of LIDAR for inspection of concrete structures.

- The MCNP research program should be used to instrument a project, collect data, analyze data, and make recommendations on how to best perform these efforts for use in predictive maintenance, conditioning monitoring, and long-term performance.
- Maintenance standards similar to what LRD is developing should help with regionalization issues.
- Inspection reports should be shared among Corps offices.

Several times during the workshop, the statement was made that periodic inspections are critical for reliable operations. These inspections are performed using different methods and techniques among the Divisions and even from District to District within a Division. For example, since Nashville District has clear water at many of its projects, many project components can be inspected without dewatering. Other important issues identified were wall armor, PLC interlocks, stability issues during tainter gate maintenance, and wire rope inspections. The funding problem faced by many offices restricts the ability to be predictive. In the long term, the fix-as-fail type maintenance is more costly. Predictive maintenance is needed for many project components since there is limited access.

Emergency repairs recommendations

- Inspection of damaged structures is recommended as soon as possible after an accident with plenty of notes and pictures so one can provide complete information.
- A conference should be held to learn about new designs for lock structural components. For example, some Districts are proposing the use of a wedge system in their quoin block designs, and others are interested in this type of design.
- A standard type procedure for documenting emergency repairs due to barge accidents is recommended.
- A pre-plan of action for navigation accidents with emergency repair guidance is recommended. Emphasis needs to be placed on “Implementation of Plan” since this was one of the lessons learned after Hurricane Katrina. Past AAR of accidents may be a good way to help organize a plan.

- Research on techniques to remove barges from dams is recommended. Projects with decks and cranes have equipment onsite that could be modified slightly to assist with removing barges.
- A review of shipping laws concerning responsibilities for accidents is recommended.

Many of the recommendations mentioned above are probably already being used in full or partially by District field offices. These recommendations are intended for HQUSACE so they can be discussed and acted on as needed.

Innovative emergency closure systems

A brief brainstorming session was held at the end of the emergency repairs session to solicit ideas from the attendees on techniques that could be used for emergency closure systems for projects. Emergency closure capabilities exist for some projects at the locks and dams, but if barges are wrapped around piers or lodged in the lock approaches, other closure methods may be required. The concepts identified by the workshop attendees who participated in this exercise were:

1. Empty barges that can be filled with water or sand and sunk
2. Transportable, stackable bulkheads
3. Gravity dam
4. Stockpile rock in accessible area and dump to close off flow
5. Emergency stoplogs with cradle system – Whitten Lock in SAM has cradle that will lower five stoplogs
6. Tension structure or tension structure with a mesh
7. Inflatable dam
8. Herter box
9. Louvered bulkheads
10. Wicket type structure with frame
11. Shuttered A-frame and top beam system – the McAlpine 600-ft lock had a system like this
12. Floating caisson.

Some of the concerns expressed for emergency closure systems were:

- Anchor points
- Should not be too expensive
- Should be able to deploy quickly
- Should be able to remove the system quickly
- Should be readily available
- Should be transportable
- Should be adjustable.

With several of the options listed above, anchor points located upstream from the dam were an essential part of the concept. A suggestion was made that possibly barges anchored to land or maybe even on land could be used as anchor points. Many of the participants in this exercise believed that using barges was a very practical solution. The salvage companies are accustomed to handling barges and they have indicated they could sink a barge for this type situation. Also many in the group thought it may be worthwhile to go ahead and establish some anchor points upstream in preparation for an emergency situation.

The use of land-based bulkheads will require some type of lifting mechanism that may not be able to reach the area of concern. Preparations should be made in advance if this type system is desired. The equipment at the project might be modified or even the dam and lock may need to be retrofitted with a system to handle the bulkheads.

The concept of using a mesh where some sort of material could be placed upstream from the mesh and the flow would force the material into the mesh is a good way to gradually reduce flow. The material could possibly be rock, steel plates, or even the needle beam type units. The louvered type unit is also a good way to lower something into flowing water and gradually reduce the flow without experiencing excessive hydrodynamic forces.

A design team composed of structural, mechanical, hydraulic, and operation and maintenance disciplines should be assigned the task of developing a prototype design. The performance of the design should be evaluated for both lock gate and spillway gate applications using existing numerical

models and later at a site representative of a typical inland navigation project. The design may need slight modifications during the evaluation.

Methods to remove barges from dams

Concurrent with the brainstorming session described above, another session was held to develop ideas associated with barges colliding with dams. There were two basic areas of discussion. One concerned equipment or methods that could be used to remove barges from a dam. The second area of discussion related to techniques that could be used to prevent barges from reaching the dam. The first area emphasized devices that can cut through or pull off barges that are already wrapped around a dam pier. Other ideas for the second discussion concerned devices/structures that could prevent barges from impacting the dam.

All agreed there should be a well thought out plan in advance of an emergency situation. The plan should be submitted through the safety office to address their concerns and get concurrence.

Cutting devices

Pete Frick, Louisville District, discussed using an integrated cutting beam suspended by a crane. This concept was highly rated and has been used to some degree in previous accidents. The system must include a method to guide and stabilize the beam.

Also suggested was an abrasive wheel saw, similar to those used for cutting concrete. The saw could be deployed from the end of the beam (preferred) or from a barge.

John Clarkson, Huntington District, suggested a pre-placed conduit and wire rope saw. The conduit would span from pier to pier. A synthetic rope would be fed through the conduit during placement. When needed, a wire rope/diamond saw would be pulled through the conduit and pulled by a crane or winch, to cut the barges in half or to a degree that the currents would break the barge apart and wash downstream. Some method to protect the conduit would be needed. The emergency stop log slots might be modified to help accommodate this design.

One of the ideas shown in the formal presentation involved an excavator placed on a barge with a hydraulic shear device attached. A problem noted

in the presentation was lack of traction on the barge deck for the excavator. One might use this technique and use turnbuckles to secure the excavator to the barge deck more securely.

A suggestion was to use underwater cutting rods (need air) for removing barges.

A related idea was to use a magnesium cutting rod/torch that works underwater.

Any tool that would be developed should probably be truck transportable to the site, because it would be faster than transporting by water. Also a low pool level may be associated with a major accident and could impede getting the tool onsite by water.

Anchors

The next idea was also considered for the emergency closure systems. Pre-placed deadman anchors on both banks upstream from the dam (both) to act as reaction points for pulling barges off the dam is probably a beneficial investment. A variation of this idea was to have some pre-placed pulling points on the bull noses of the piers.

Large ship anchors could possibly be dropped upstream from the dam and used to pull from. It was noted that this idea is very sediment-dependent. Sufficient depth of sediment would be required to get the necessary holding power, and this would not work with rock.

A grappling hook device with barbs that extend once they pass through the hull/deck (similar to the barb on a speargun) could be shot into the barge to provide an easily attachable pulling point.

A centralized barge with winches for pulling barges off the piers might be good for regional accidents.

A winch system could be installed on each pier to help pull barges off the piers.

Prevention methods

Placing drilled piles 100 to 200 ft in front of the dam piers may prevent barges from impacting the piers either by blocking or deflecting them. These piles would need to be braced and be very robust to withstand the impacts.

Placing a design on the dam piers similar to the cow catcher noses on the older locomotives was also suggested. This would be easier for new construction. Retrofitting existing projects would probably require extensive modifications. A variation of this idea is to place beams with a braced angle in front of the dam piers most likely to be impacted.

General comments on barge accidents

If HQUSACE and field offices consider the problem of removing barges from dams to be significant, then further investigations are needed, and the salvage companies (they have a national association) should be contacted to supplement the ideas presented above. If they can come up with a better tool, then the Corps would be more likely to hire them.

The Department of Homeland Security might be interested in helping to pay for further study and tool development because of the need to recover from these types of accidents. They might be more interested in the ideas that prevent barges from impacting dams, such as the preplaced piles/piers or the floating boom.

One idea was to work with the Coast Guard to define the situations when accidents are most likely to occur. The tow boat operators could then be warned that the situation is dangerous. However, subsequent discussions noted that accidents still happen even under good conditions due to other factors such as poorly maintained towboats and human error.

Appendix A: Workshop Announcement

FY06 Navigation Lock and Dam Inspection and Emergency Repairs Workshop
Waterways Experiment Station (WES)
Vicksburg, Mississippi

April 18-20, 2006

Problem: Due to age and reduced funds for maintenance and rehabilitation, many Corps navigation locks and dams are in danger of failure. Inspecting the locks and dams, particularly the underwater portions, is difficult. Also, when failures occur (e.g., in lock gates or dam gates), existing methods to mitigate the failure are often difficult and time-consuming to install, and effectiveness is in some cases marginal.

Workshop Purpose: The workshop will have two primary purposes: 1) looking at procedures for lock and dam inspections; and 2) examining existing emergency repair capabilities and brainstorming improvements.

From the inspection perspective the following issues will be addressed:

District/Division staff will identify present lock and dam inspection techniques and highlight difficulties due to lack of suitable equipment/technology (other difficulties may be staffing and/or reporting and documentation).

ERDC staff will describe current research and development (R&D) efforts to address these problems and new tools that can be used.

Industry will be invited to give their input, for example, existing technology that may not be in common use on Corps projects (e.g., the offshore oil industry, recent improvements in hydrographic survey equipment, software, etc.).

On the emergency repair capabilities topic the following issues will be addressed**:**

Districts/Divisions will be asked to describe equipment and technologies currently available for emergency repairs of locks and dams and any planned improvements.

ERDC staff will describe results from a 2005 modest innovative technologies R&D effort on possible emergency mitigation techniques and current research on hydraulic design of emergency repair/avoidance structures (e.g., booms to keep runaway barges from impacting dam gates during high flows).

The group will brainstorm new and innovative emergency repair devices (e.g., inflatable gates) or devices that could be used to reduce the likelihood of accidents that cause emergencies.

Dates: Tentative Dates are Tuesday through Thursday, 18-20 April 2006 (2.5 days)

Location: Conference Facility in Coastal and Hydraulics Laboratory, WES

Desired Outcomes:

Workshop summary consists of a Web site with PowerPoint presentations, notes from the discussion, and recommendations, both for the Corps as a whole and the Navigation R&D program in particular.

Existing regulations on inspections will be examined and recommendations for improvement provided.

Potential Workshop Topics

Inspection Procedures

Locks (including walls, miter gates, machinery, others?)

Dams (scour, gates, anchors, machinery, downstream protection, others?)

a. Current inspection procedures/scheduling
b. Problems with current procedures/equipment
c. Relevant ongoing research and any gaps
d. Applicable offshore oil industry capabilities
e. Issues related to abnormal conditions (flow, stage)
f. Current emergency repair techniques (bulkheads, others).
g. Preventive methods to handle emergency closures (existing, planned)
h. How to anticipate how components will function under extreme conditions
i. Emergency closures – what causes problems; quicker ways to respond to problems
j. Risk and reliability
k. Recovery salvage planning
l. Techniques to map cracking on chamber walls
m. Underwater inspection techniques
n. Analysis of high-water-related accidents on the Ohio River in Jan 05, potential preventative measures and repair/salvage options in case of an accident

Contacts: For additional information, to suggest topics, or to be added to the distribution list, contact:

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Appendix B: Final Agenda

Navigation Lock and Dam Inspection and Emergency Repairs Workshop
U.S. Army Engineer Research and Development Center (ERDC)
18-20 April 2006
Vicksburg, MS

General Session

18 April
Facilitator: Jim Clausner, ERDC

Topic	Facilitator or Presenter	Schedule
Welcoming remarks	Dr. Bill Martin, ERDC - CHL	0800 – 0810
Administrative remarks	ERDC	0810 - 0815
Introduction and future outlook for Corps navigation work	Mike Kidby HQ USACE	0815 – 0840
Navigation challenges in Mississippi Valley Division	Jim Hannon, CEMVD	0840 - 0900
Navigation Systems Research Program	Jim Clausner, ERDC - CHL	0900 – 0920
Engineering reliability analysis for prioritizing investment decisions	Larry Dalton, CELRL	0920 – 0950
Break		
Standardization of lock design	Jeff Stamper, CEMVS	1010 – 1040
Robotics	James Lever ERDC - CRREL	1040 -1110
Lunch		1110 -1230

Lock & Dams Inspection Session

18 April
Facilitators: Guillermo Riveros and Jim Evans, ERDC

Topic	Facilitator or Presenter	Schedule
Current inspection policies for hydraulic steel structures (gates)	Joe Padula ERDC - GSL	1230 - 1255
Current inspection policies for lock walls	Tom Mack Roger Less MVR	1255 - 1320
Inspection techniques used in Mel Price miter gate	Tom Ruf CEMVS	1320 - 1345
Inspection techniques used on LaGrange lock walls	Anne Werner CEMVR	1345 - 1410
Break		1410 - 1430
Evaluation of existing wire rope tainter gates, in accordance with EM 1110-2-2702	Shahir Safi CENWK	1430 - 1455
Jamie L. Whitten Lock and Dam culvert repair and inspection	Harry Stone CESAM	1455 - 1520
Periodic inspections	Phillip Sauser CEMVP	1520 - 1545
~~Discrete Sensors~~	~~Bruce Barker ERDC - ITL~~	~~1545 - 1610~~
Acoustic camera	Jim Evans ERDC - ITL	1610 - 1635

Lock & Dams Inspection Session con't

19 April
Facilitators: Guillermo Riveros and Jim Evans, ERDC

Topic	Facilitator or Presenter	Schedule
ERDC sponsored research		
Infrastructure asset management	Sandra Knight ERDC	0800-0825
Numerical evaluation of stress intensity factors: J-Integral approach	Guillermo A. Riveros ERDC - ITL	0825-0850
Nondestructive condition monitoring for tensioned steel members	Michael McInerney CERL	0850-0915
Break		0915-0935
Acoustic techniques	Randy Scheib RDTEC	0935-1000
~~Instrumenting Structures~~	~~Bruce Barker ERDC - ITL~~	~~1000-1025~~
Laser scanning	Mike Harvey Leica Geosystems	1025-1050
New techniques for condition assessment and monitoring of deteriorated concrete	Rick Haskins ERDC - ITL	1050 - 1115
Currents in lock approaches	Michael Winkler	1115-1140

Emergency Repairs Session

19 April
Facilitator: John Hite, ERDC

Topic	Facilitator or Presenter	Schedule
Repair of quoin seals at Hannibal Locks and Dam	Jim Fisher Dave Sneberger CELRP	1300-1325
Belleville Locks and Dam barge accident	John Clarkson CELRH	1325-1350
Barge in dam gates, Smithland, Cannelton	Pete Frick CELRL	1350-1415
McAlpine Lock emergency closure	Pete Frick CELRL	1415-1430
Break		1430-1450
Emergency repairs at John Day Lock and Dam	Matt Hanson, Reed McDowell, CENWP	1450-1515
Upper Mississippi spare gate system	Jim Wilson CEMVR	1515-1540
Columbia Lock and Dam, Ouachita River, repair of tainter gate strut arm damaged by barge impact	Ed Chisolm/Ed Schilling CEMVK	1540-1605
Mel Price Lock and Dam gate repairs	Tom Ruf CEMVS	1605-1630

Emergency Repairs Session con't

20 April
Facilitator: John Hite, ERDC

Topic	Facilitator or Presenter	Schedule
Hydrodynamic design emergency structures	Howard Park ERDC	0800-0825
Navigation problems due to outdraft	Howard Park ERDC	0825-0850
Instrumenting structures	Bruce Barker ERDC – ITL	0850-0915
~~Industry Perspective on Emergency Closures and Repairs~~	~~Sammy Dickey, RIAC~~	~~0850-0915~~
Break		0915-0935
LRD's maintenance standard	Bob Willis LRD	0935-1000
Wrap-up session discussion of policy and recommendations for any changes	All	1000-1100
Brainstorming session for innovative emergency structures	Group Participation	1100-1200
Adjourn		1200

Appendix C: Registration List

Navigation Lock and Dam Inspection and Emergency Repairs Workshop
18-20 April 2006
U.S. Army Engineer Research and Development Center (ERDC)
Vicksburg, MS
List as of 4/17/06

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14. ABSTRACT

The U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Laboratory hosted a "Navigation Lock and Dam Inspection and Emergency Repairs" workshop on 18-20 April 2006. The workshop was sponsored by the Navigation Systems Research Program and was attended by over 70 people from the Corps Districts, Divisions, and the ERDC laboratories as well as industry representatives. The primary purposes of the workshop were to examine current procedures used by the Corps for inspection and emergency repairs by presenting case studies and experiences and follow up on these discussions with suggestions and recommendations for improvement. Ongoing ERDC research and development in the areas of inspection and emergency repairs was also presented. The proceedings from the workshop will be available in the near future on the CHL Web site.

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